New Proposal: Characterization and Manipulation of Ellipsoidal Electron Bunches Generated from Cs_2Te Cathodes *via "space-charge explosion"*

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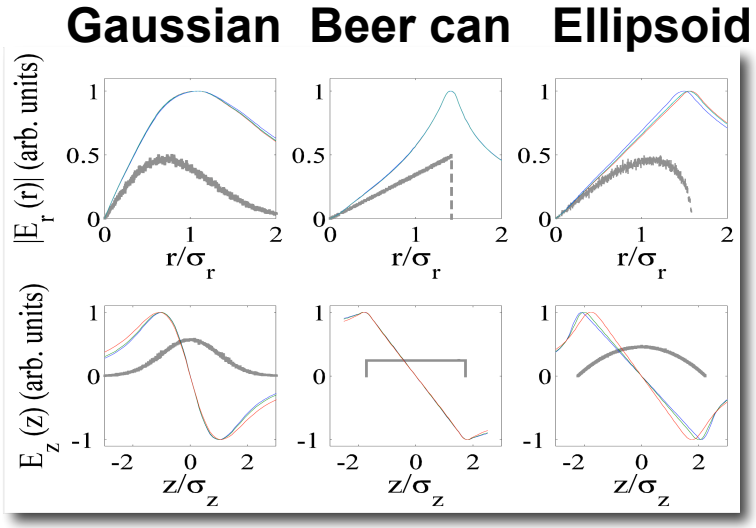
“Self-generating” ellipsoidal bunches

- In uniform ellipsoid distributions, space charge force are linear with respect to position
  ⇒ **ideally no emittance growth!**
- A “self generating” scheme to produce ellipsoidal bunch via photoemission was proposed by L. Serafini [AIP**413** (1997)] and J. Luiten et al. [PRL**93** (2004)]

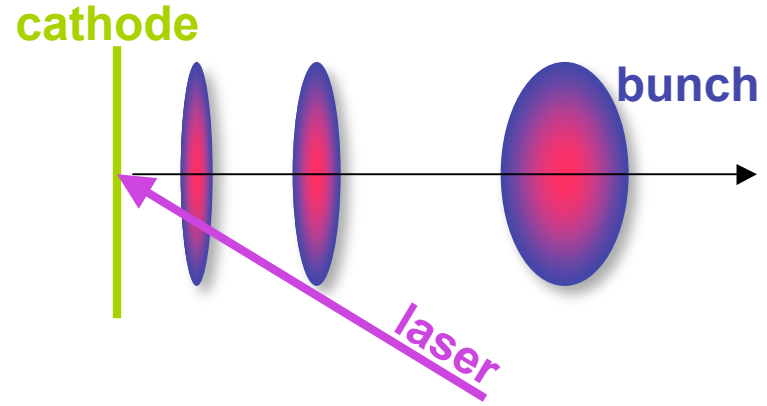


should work at A0

$$\frac{eE_0 c\tau_l}{mc^2} << \frac{\sigma_0}{\varepsilon_0 E_0} << 1$$

=0.001 for τ_l=50 fs, E=50 MV/m

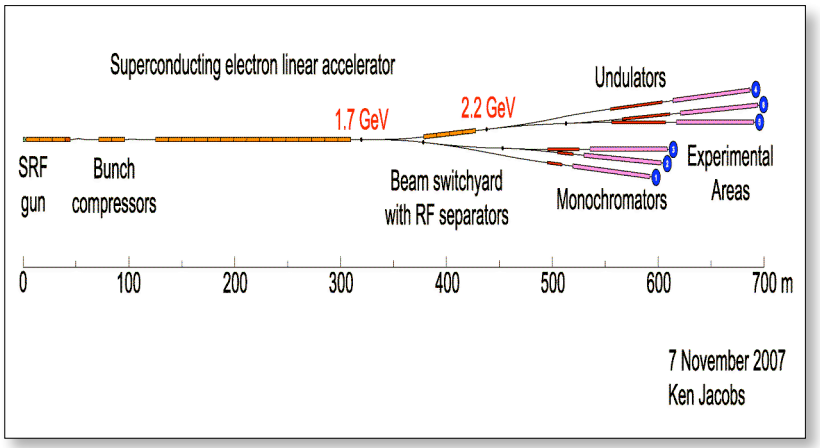
=0.1 for Q=100 pC, R=1 mm



- Recently demonstrated with **metal cathodes** and **out** of an rf-gun see:
  - P. Musumeci, et al., PRL **100**, 244801 (2008) and,
  - J. Luiten et al., presented at AAC’08 (2008).

Motivation

- WiFEL seeded soft x-ray FEL proposed to NSF relies on ellipsoidal bunch generation from Cs_2Te cathode with gradient and charge similar to A0 parameters. Important proof of principle experiment with this cathode material and gradient.



- MIT compact x-ray source based on inverse Compton scattering also relies on similar experimental parameters. Demonstration of dogleg compressor with positive R_{56} and low energy is also important.

- Operate A0 in a *new regime* will low transverse emittances (sub-μm) and possibly short electron pulse duration (~100 fs)

- This could foster a novel exciting Beam Physics program with the **present configuration** and possibly minor beamline reconfiguration.

Goals & Originalities

- **Goals:**
  - Generation and phase spaces characterization of a low emittance ellipsoidal bunch for a wide variety of operating conditions (e.g. charge, laser parameters, etc…).
  - Compression at low energy of an ellipsoidal bunch.

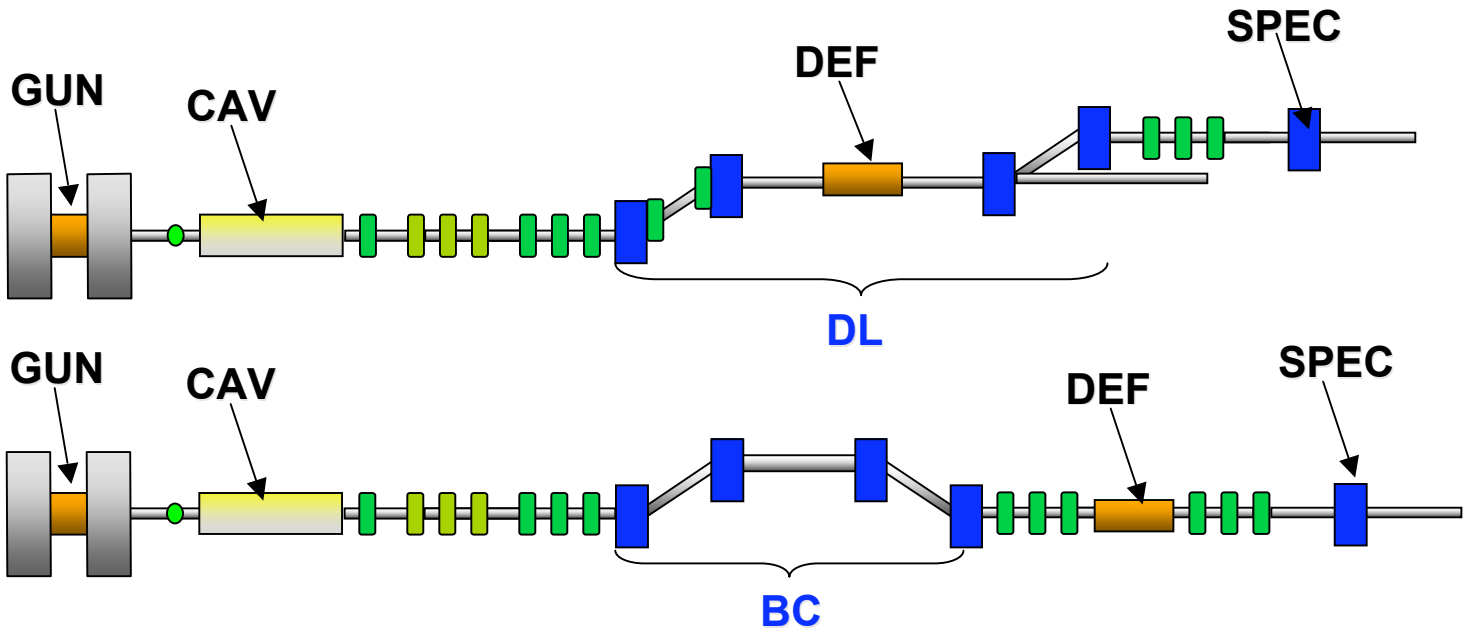
- **Originalities:**
  - 1st generation of such beam from Cs_2Te cathode
  - 1st generation in an L-band gun (with significantly lower E-field compared to S-band)
  - A downstream accelerating cavity (and possibly bunch compressor) would provide means to tune the (z,δ) correlation and possibly compress the beam (**nobody did this!**)
  - Eventually could revisit some of A0's favorites i.e. magnetized and flat beam generation using ellipsoid bunches etc…

Experimental setup(s)

- The experiment does NOT requires any significant beamline upgrade: we plan on reusing/sharing all the hardware already installed in A0.

- Present gun (assumed to produce E_{peak}= 35 MV/m).
- Current 9-cell cavity (assumed to provide E_{peak}= 24 MV/m).

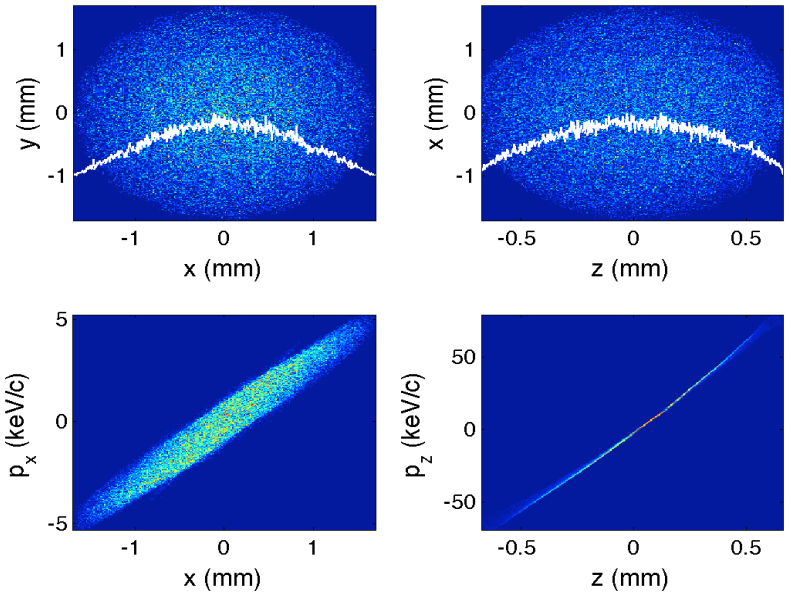
- Bunch compression would also bring exciting possibilities.



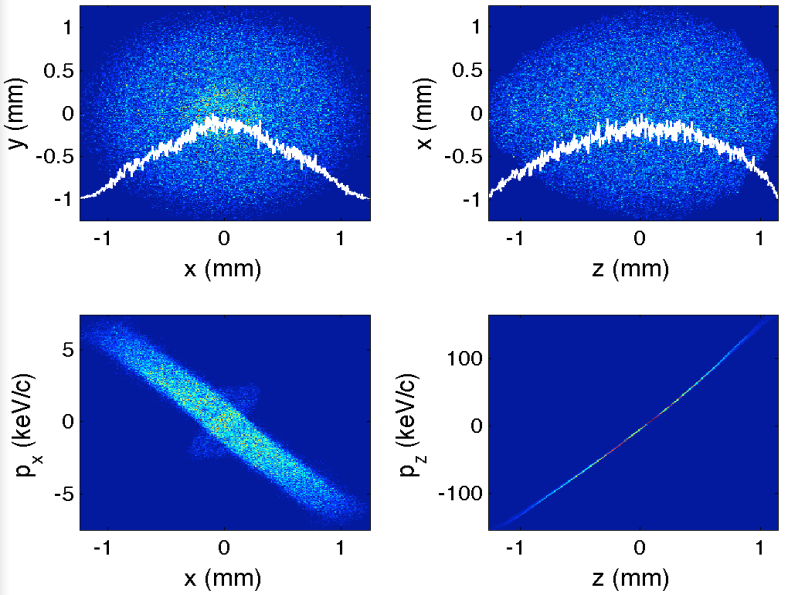
Anticipated results I

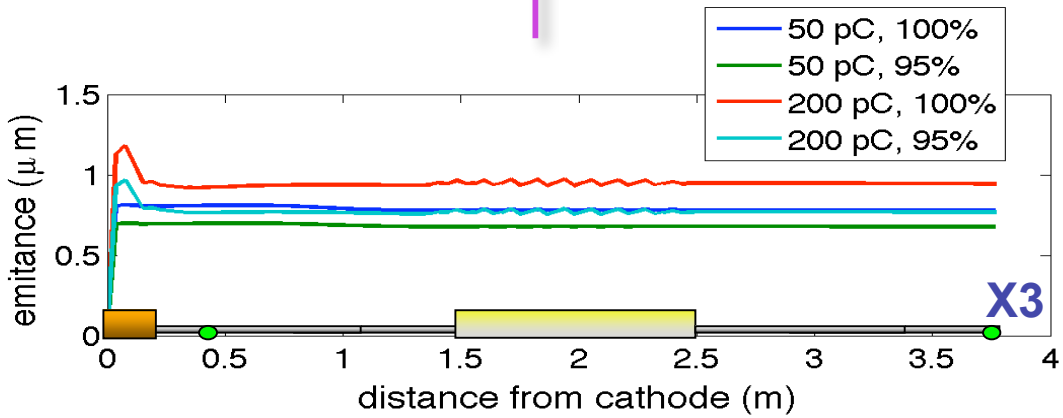
- **Preliminary** studies (no thorough optimization) are very encouraging

X3: 50 pC



X3: 200 pC



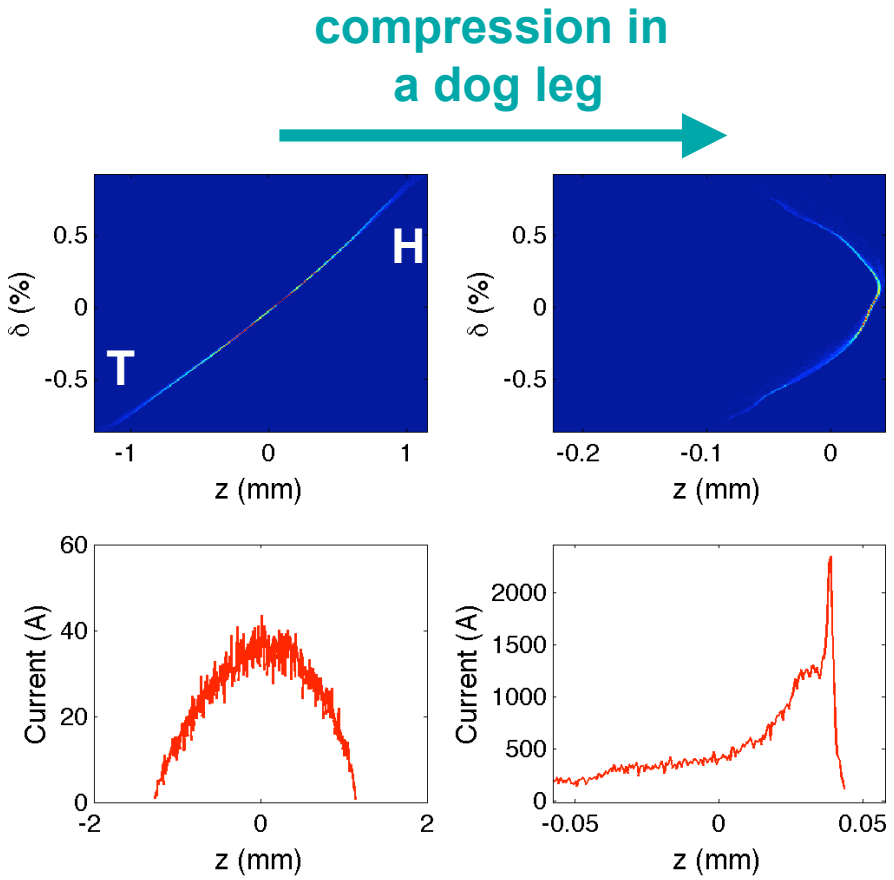


Anticipated results II

- Possibility to compress the bunch and reach multi kA peak current

- Chirp imparted by linear space charge has the proper sign for compression in a dogleg type compressor

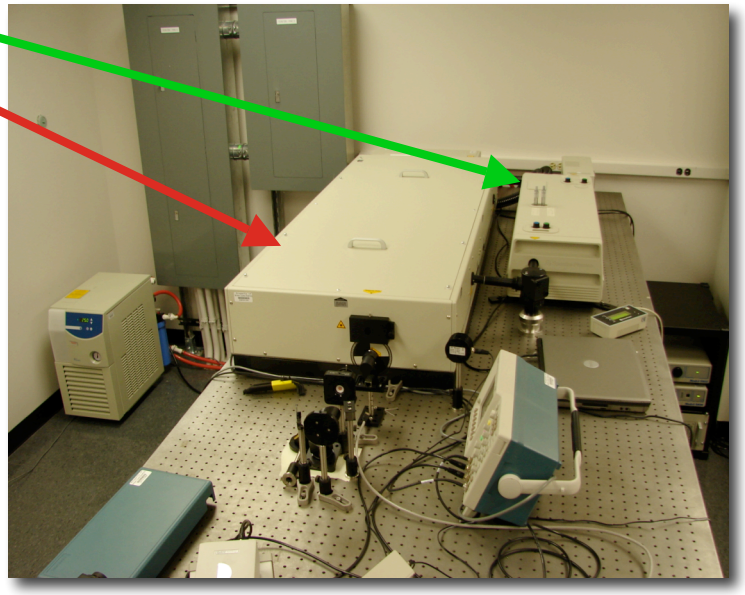
- Can also compress in a chicane but would have to operate the accelerating cavity far off-crest.
  ⇒ **low energy**



Q~200 pC

Laser

- NIU owns a Tsunami (tuned for 40th harmonic of 2.856 GHz) with SpitFire-Pro F-XP
  - **output pulse energy > 3.5 mJ**
  - **rms pulse length < 50 fs at 800 nm**
  - **repetition rate 1 kHz**



- NIU has money to buy a new oscillator. As soon as this proposal would be "approved" (= commitment to provide time) we will order an oscillator operating at 1300/16=81.25 MHz

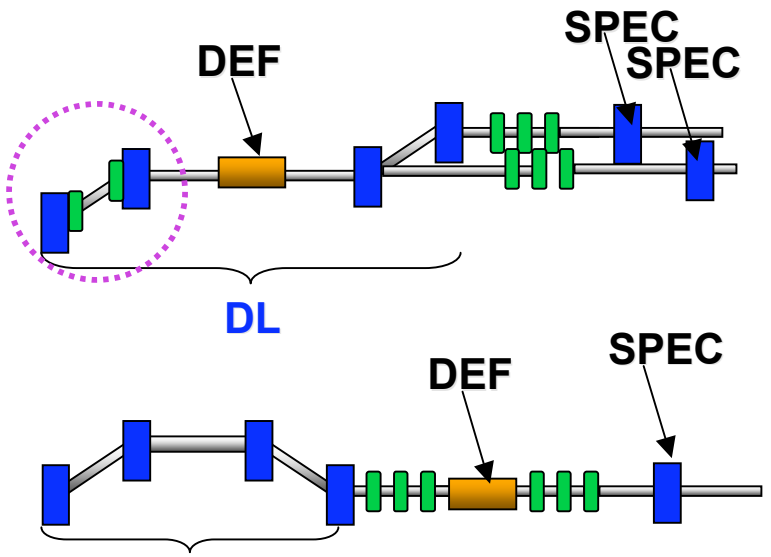
- Frequency conversion to uv needs to be changed (3ω versus 4ω). This will be done at NIU with help from ANL and FNAL.

- New oscillator would be directly delivered and installed at A0. Amplifier would be temporally moved from NIU to A0.

Beamline requirements

- We need to fix the gun klystron problem [the gun should (but this is not a must) provide >35 MV/m]

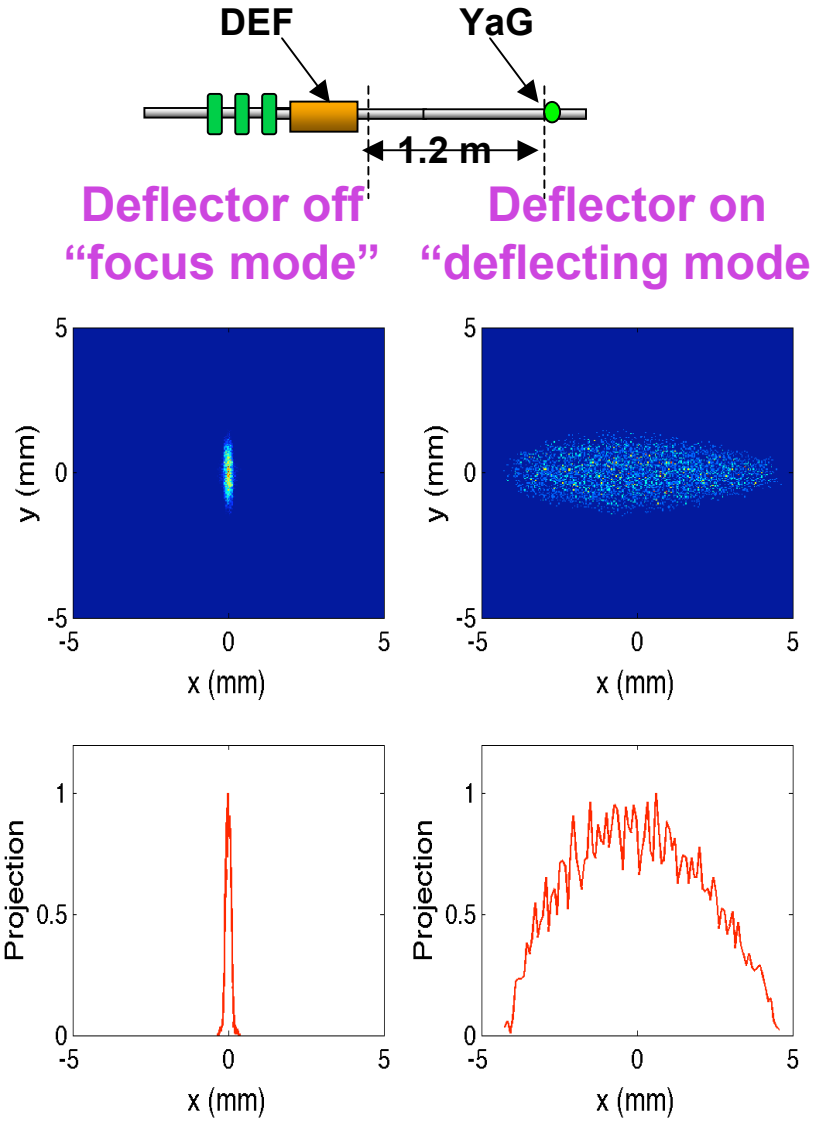
- We need to investigate the best scheme for compression of ellipsoidal bunches at A0
  - Dogleg is the natural choice (SC-induced energy chirp) but might complicate experiment.
  - Compressor is easier but not "elegant" low energy due to needed chirp and would require a significant beamline reconfiguration (not compatible with εX?).
  - Thorough beam dynamics studies need to be performed.



Diagnostics

- Horizontally deflecting cavity (currently used in the exchanger) can provide the proper kick to resolve ~100 fs (taking k~3 m^{-1} at 15 MeV)

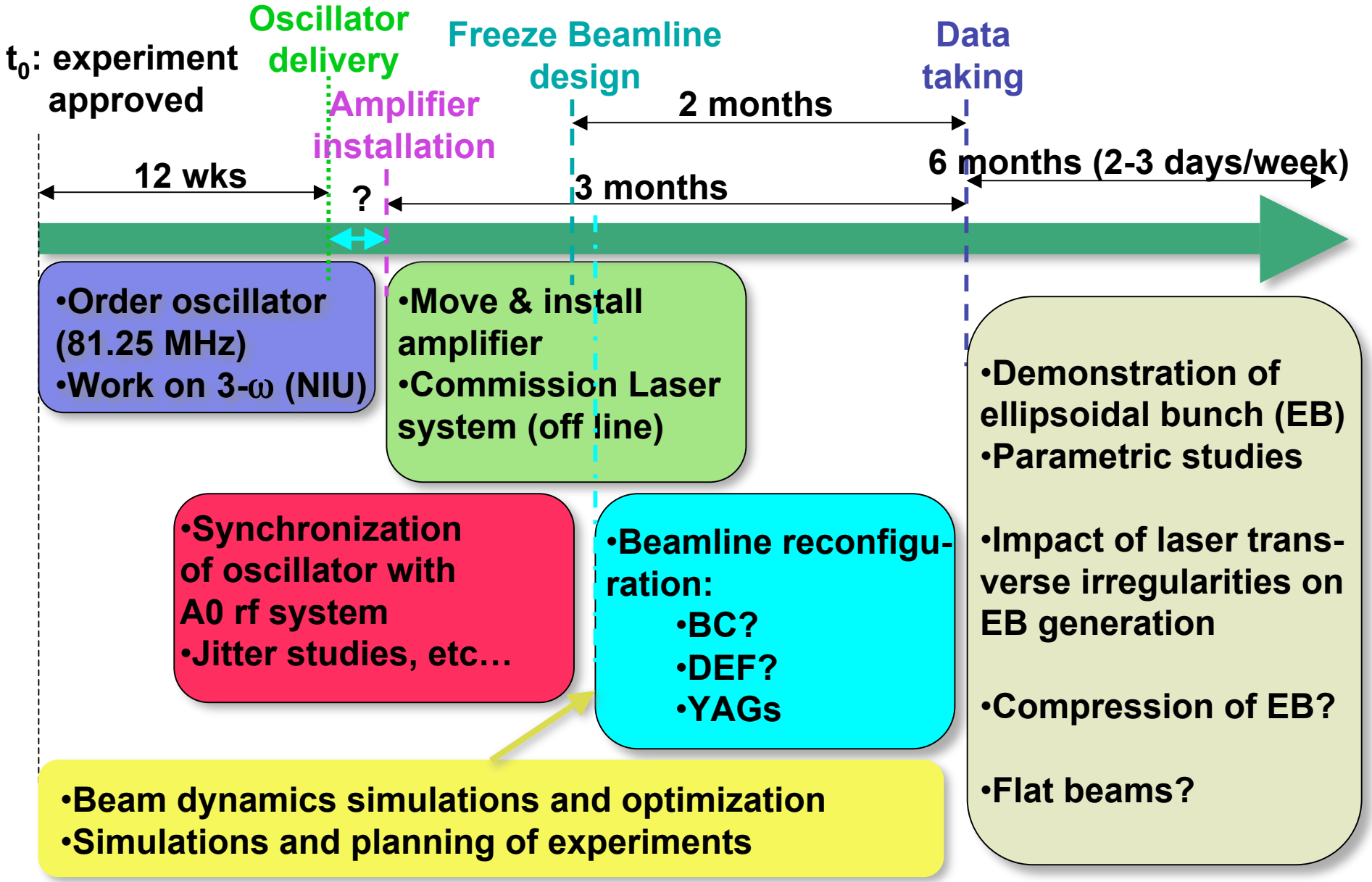
- Standard transverse view screens would be needed; probably most OTR screens would need to be changed to YaG to be sensitive to "low" charge operation (~100 pC) in single bunch mode (but **this is also needed for εX experiment at some point**)



Staffing & Hardware

- **NIU**
  - provide laser for 6 months to 1 year (oscillator for a longer period, but amplifier only during the time of the experiment)
  - Students [one graduate (will work on laser his dissertation related to EO imaging), and most probably undergrads].
- **UW/MIT**
  - R. Legg (UW), W. Graves (MIT) plan on taking part to experiment and data analysis. MIT and UW would possibly involve student(s).
- **ANL**
  - J. Power could help with 3-ω conversion + take part to experiment
- **Expectation from FNAL**
  - J. Ruan's involvement in laser settings & operation/analysis, Y.-e Sun's involvement in measurements & operation/analysis, J. Santucci for operation support, and techs+ minor hardware for beamline configuration.
  - Financial support for a part-time guest scientist [D. Dowell, few weeks (?) during data tacking (TBD)].

Proposed Schedule



Summary

- We proposed an experiment to produce, characterize and manipulate ellipsoidal bunches at A0.
- Preliminary simulations (beam dynamics and diagnostics) support the feasibility of such an experiment
- The use of Cs_2Te photocathodes and the possibility to accelerate and manipulate (e.g. compress) such an ellipsoidal bunch present **innovative and challenging** Beam Physics problems.
- At least four external institutions have **strong interest** and are ready to **collaborate**. Some of them are considering possible **commitments** either in hardware or manpower [NIU's commitment would amount to ~0.4 M$ (half would be a long term loan to A0)]
- **BUT:** in order to be the **first** to perform such an experiment, **we need to proceed promptly**. If approved (and compatible with A0 schedule), **we could start taking data in March 2009** and could **bring exciting physics during FY09**.
- Eventually a new photocathode laser could foster exciting novel activities.